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Quality Assessment of Resampled Digital Images by Statistical Metrics

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Abstract

The visual degradation of resampled (downsampled and then upsampled to the original size) greyscale digital images is quantified by local luminance, contrast and structure statistical comparison indexes. Spatial distributions of these indexes are shown. The global quality of resampled image is quantifiedby the similarity index defined by median values of local indexes. Parameters of this index consistent with the median opinion score are determined. The dependence of global indexes on the size of downsampled image is presented.

Keywords: image quality, image resampling, similarity index

Digital image resampling is a technique used to change its size in pixels. Increasing the number of image pixels is called upsampling, whereas reducing this number is called downsampling. Upsampling involves interpolation to estimate values of new added pixels, whereas downsampling involves computing new pixel values as weighted averages of the original image pixel values in their surroundings. Resampling techniques are based on a curve called resampling kernel that defines relative weights of the original image pixel values depending on their distance from the new pixel. Downsampling decreases the amount of information in the image and upsampling downsampled image will not restore all the original image details. The visual quality of such images is degraded.

The aim of this paper is to quantify the quality of digital image downsampled to a given size and then upsampled to its original size. In resampling we used Lanczos-windowed kernel which is the normalized sinc function: $sinc(\pi x)/\pi x$ for $x \neq 0$ and *1* for $x = 0$. We considered grayscale digital image, because color image can be treated as three grayscale images which are individually resampled. The perceptual quality of distorted image we assess assuming that the original image is available. Traditional full-reference image quality metrics based on the measure of differences between distorted and reference images. In recent years metrics based on the degradation of structural information have been developed (Pappas, Safranek, Chen, 2005, p. 1; Wang, Bovik, 2002; Wang, Bovik, Sheikh, Simoncelli, 2004, p. 3–4).

The grayscale original image we consider is shown in figure 1. This image is 2048 pixels in width and height and it has 8 bits/pixel, i.e. pixel values can assume 256 gray levels. The position of a pixel in the *i*th raw and *j*th column we denote by (i, j), where $i, j = 1, \dots, n$. Distorted images obtained by downsampling the original image to different sizes n and then upsampling to the original size are shown in figure 1. Their correlation coefficients with the original image given in this figure are too high to represent human perceptual image quality. The similarity measurement between the original and distorted image can be separated into three comparisons: luminance, contrast and structure (Wang et al., 2004, p. 2). We define the local luminance comparison index (*LLCI*), the local contrast comparison index (*LCCI*) and the local structural comparison index (*LSCI*) as:

$$LLCI(i,j) = \frac{2\mu_D(i,j)\mu_O(i,j)}{\mu_D^2(i,j) + \mu_O^2(i,j)} \tag{1}$$

$$LCCI(i,j) = \frac{2\sigma_D(i,j)\sigma_O(i,j)}{\sigma_D^2 + \sigma_O^2(i,j)} \tag{2}$$

$$LSCI(i,j) = \frac{K(i,j)}{\sigma_D(i,j)\sigma_O(i,j)} \tag{3}$$

where $K(i,j)$ is the covariance between distorted and original images. $\sigma_D(i,j)$ and $\sigma_O(i,j)$ are standard deviations, whereas $\mu_D(i,j)$ and $\mu_O(i,j)$ are mean values of distorted and original images. These quantities are calculated within the local window centered at the position (i,j). We used square window of size $m = 11$ and circular-symmetric Gaussian weighting function with standard deviation $(m-1)/6$ normalized to unit sum. When a denominator in any of the above formula was zero, we incresed m by 2 until it was different from zero. We normalized local indexes$L(i,j)$ according to the following formula:

$$L_n(i,j) = Byte\left(Round\left(255\frac{L(i,j) - L_{min}}{L_{max} - L_{min}}\right)\right) \tag{4}$$

where $L_n(i,j)$ is the normalized local comparison index, L_{max} and L_{min} denote the maximum and the minimum of the local index value and the function $Round(\dots)$ rounds its argument to the nearest integer. Spatial distributions of normalized local comparison indexes for distorted images downsampled to different sizes are shown in figures 2 and 3. In these images the pixel grey level corresponds to the value of the local normalized comparison index.

We assumed that median values of local comparison indexes define the following global indexes: the luminance comparison index (*LCI*), the contrast comparison index *(CCI*) and the structural comparison index (*SCI*).

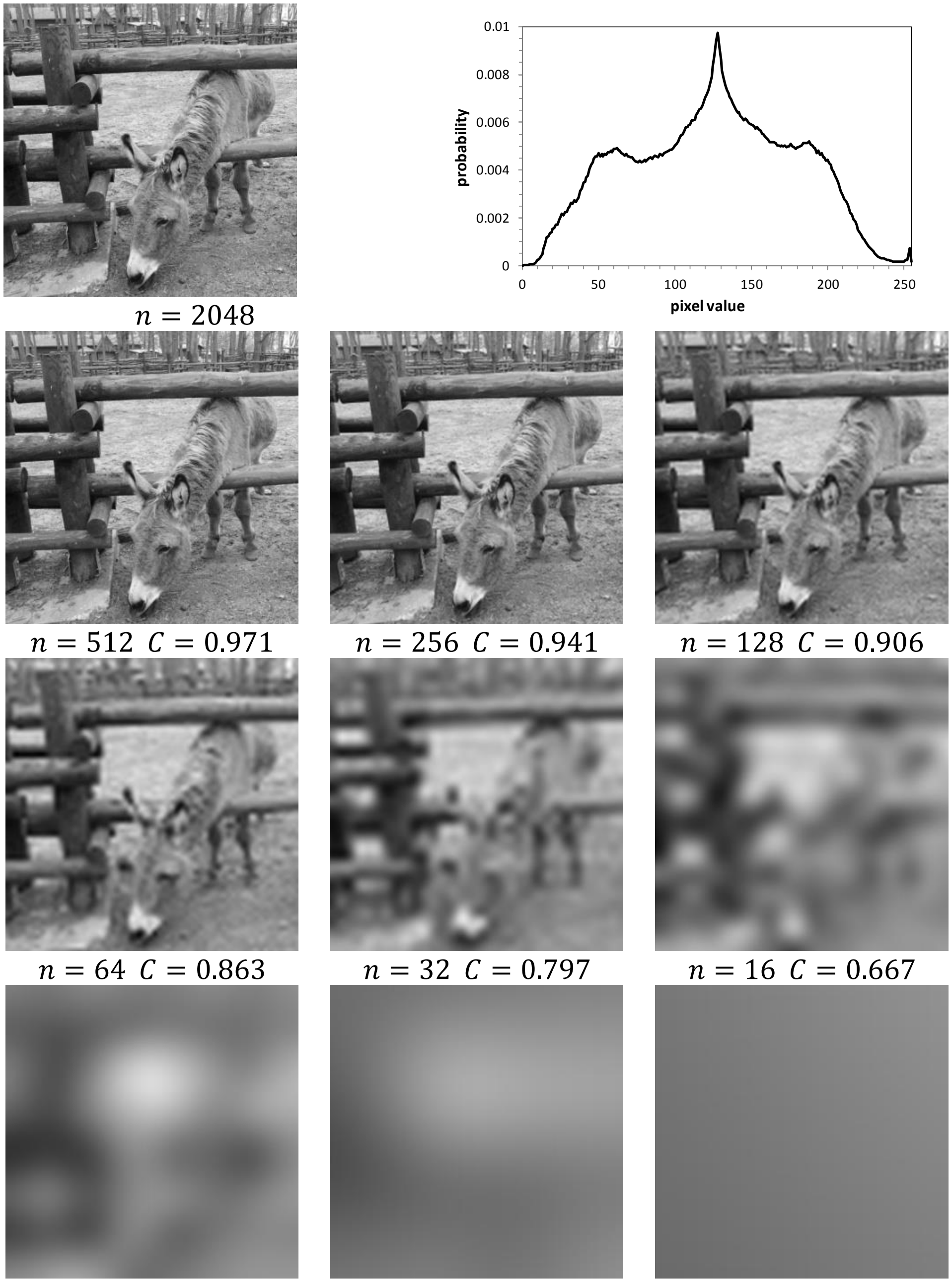

Fig. 1. The original image and its histogram (first row) and images downsampled to the size n and then upsampled. C is the correlation coefficient with the original image

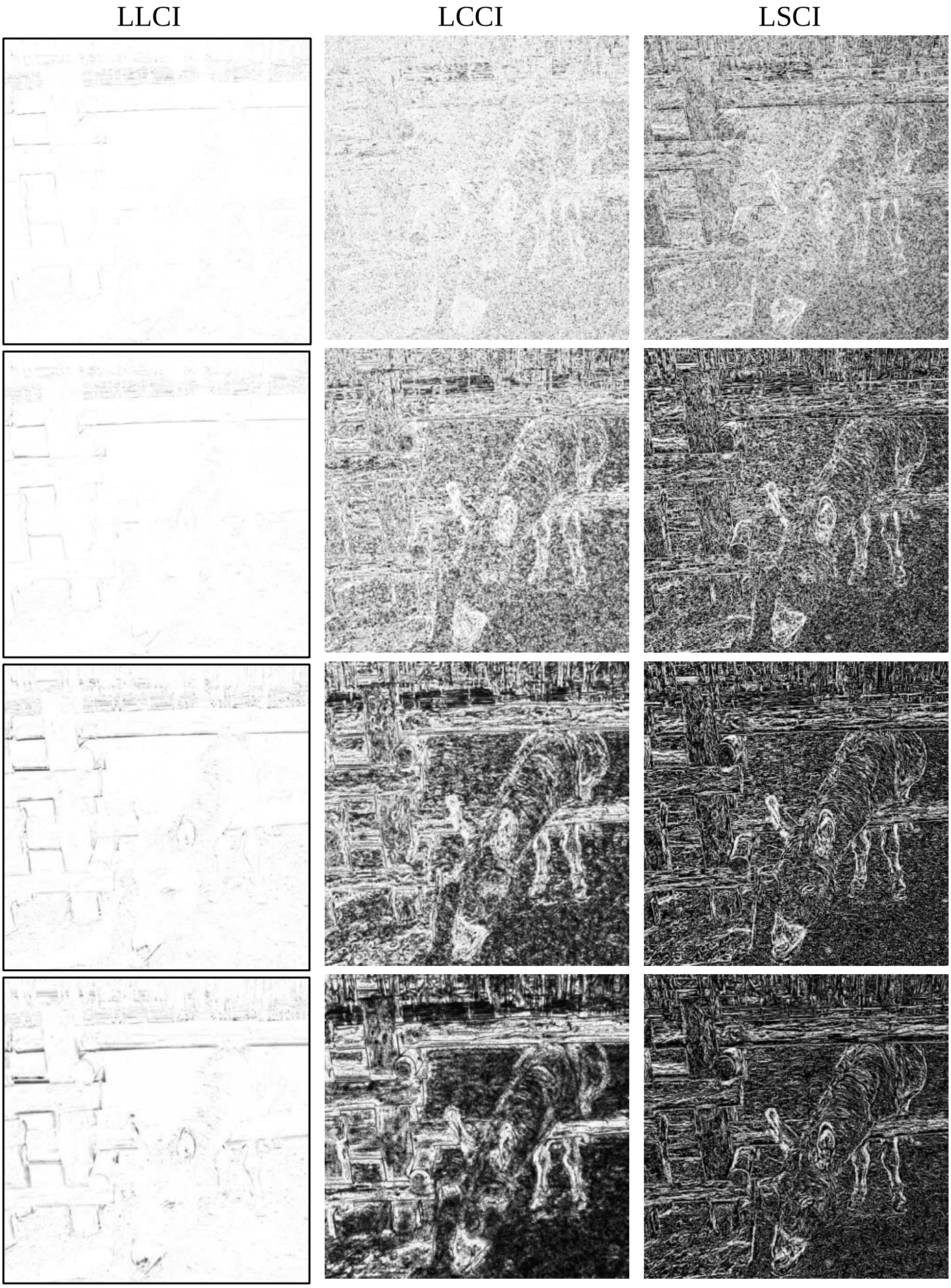

Fig. 2. Spatial distributions of local indexes LLCI, LCCI and LSCI for images downsampled to the size n : 512, 256, 128 and 64 (from the first to the fourth row)

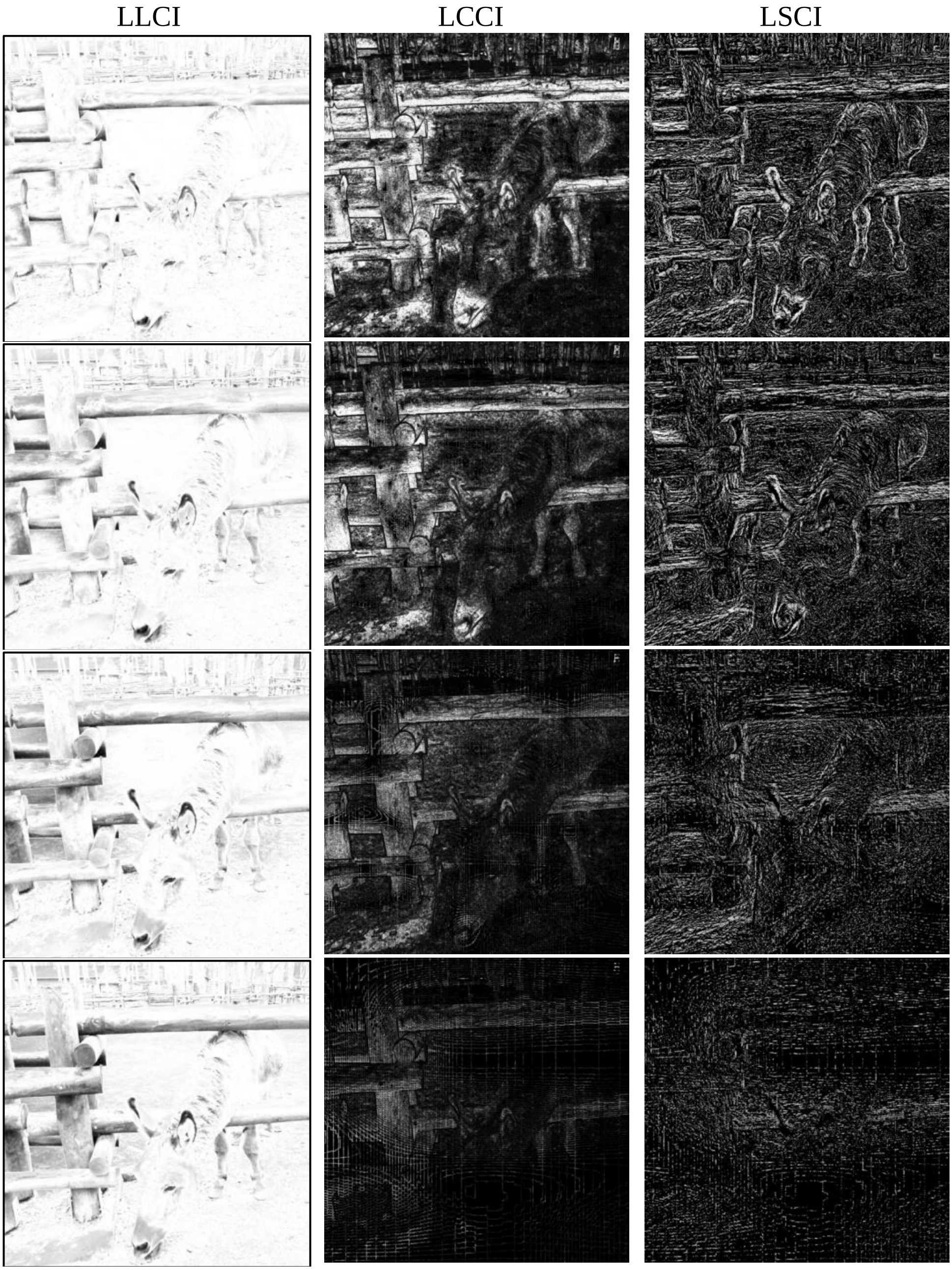

Fig. 3. Spatial distributions of local indexes LLCI, LCCI and LSCI for images downsampled to the size n : 32, 16, 8 and 4 (from the first to the fourth row)

We quantified the overall degraded image quality by the similarity index (*SI*) calculated as the median of the local similarity indexes (*LSI*) defined as: $LSI(i,j) = LCCI^{\beta}(i,j)LSCI^{\gamma}(i,j)$, where β and γ are parameters. We fitted these parameters to experimentally obtained median opinion score (*MOS*) and we obtained $\beta = 0.8$ and $\gamma = 0.1$. In figure 4 we show the dependence of global indexes, the median opinion score and the correlation coefficient on the size of downsampled images.

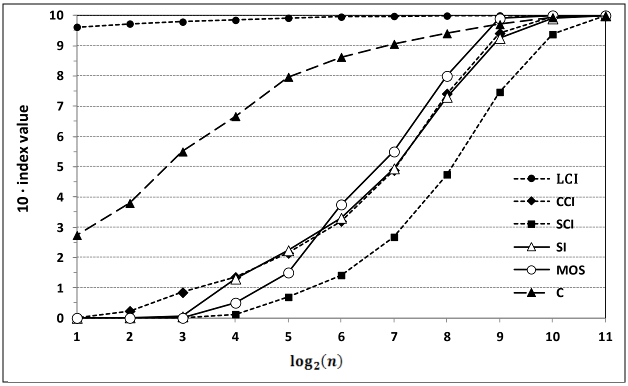

Fig. 4. The luminance LCI, the contrast CCI and the structure SCI global comparison indexes, the similarity index SI ($\beta = 0.8$, $\gamma = 0.1$), the median opinion score MOS and the correlation coefficient C for images downsampled to the size n.

Literature

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